GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 12/6/80

Project Title: Microprocessor-Based Process Control for Solar/Agricultural Applications

Project No: E-21-631

Project Director: Dr. J.H. Schlag

Sponsor: U.S. Department of Agriculture; Science and Education Administration; Suite 103; Rosslyn Commonwealth Bldg.; 1300 Wilson Boulevard; Arlington, VA 22209

Agreement Period: From 9/15/80 Until 9/30/81

Type Agreement: Grant No. 59-2134-0-6-008-0

Amount: $46,300 USDA
$36,822 GIT (E-21-358)
$83,122 TOTAL

Reports Required: Quarterly Progress Reports; Final Technical Report

Sponsor Contact Person (s):

Technical Matters

Dr. James L. Butler, Manager
SEA Southern Agricultural Energy Center
Coastal Plain Experiment Station
Tifton, Georgia 31793

Note: Follow-on to E-21-662

Contractual Matters
(thru OCA)

U.S. Department of Agriculture
Science and Education Administration
Suite 103, Rosslyn Commonwealth Bldg.
1300 Wilson Boulevard
Arlington, VA 22209

Gene P. Spory
Authorized Departmental Officer
(703) 235-2680

Defense Priority Rating: None

Assigned to: Electrical Engineering (School/~~Laboratory~~)

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
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GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 2/10/84

Project No. E-21-631*

School/~~Lab~~ Electrical Engr.

Includes Subproject No.(s)

Project Director(s) Dr. J. H. Schlag GTRI / ~~GIT~~

Sponsor U. S. Dept. of Agriculture, Science and Education Administration

Title Microprocessor-Based Process Control for Solar/Agricultural Applications

Effective Completion Date: 9/30/81 (Performance) 9/30/81 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [x] Final Report of Inventions
- [x] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

*NOTE: This Termination Sheet does not apply to project with duplicate number E-21-631/Huddleston/EE (which is a recent subproject under A-3667/Fuller/ECSL).

Continues Project No. Continued by Project No.

COPIES TO:

Project Director (Schlag)
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Other

Form OCA 60:1028

E21-631

PROGRESS REPORT

GEORGIA TECH RESEARCH INSTITUTE

PROPOSAL ENTITLED

MICROPROCESSOR-BASED PROCESS CONTROL
FOR SOLAR/AGRICULTURAL APPLICATIONS

Dr. J. H. Schlag & Dr. A. P. Sheppard

May 19, 1981

PROGRESS REPORT

The major objective of this work is to design a versatile microprocessor control system for the efficient use of direct solar energy and biomass fuel in various agricultural applications, such as crop drying, methane generation, and space heating of rural structures. This year's work has concentrated on the basic control problem, including uncontrollable inputs (temperatures of ambient air and of solar-heated air), controllable inputs (rates of air flow of ambient air and of solar-heated air, also the amount of biomass-fueled heat), and desired outputs (resultant temperature and humidity).

Development of the basic feedback algorithm has included the following parts: (1) extreme performance determinations for each mode of the system; e.g., given that ambient air and solar-heated air are used (no biomass-fueled heat), what are the maximum and minimum temperatures or humidities which can be produced; (2) feasible modes determination; i.e., given a desired output vector of temperature and humidity with a specific set of uncontrollable inputs, find those modes of the system which make the desired output possible (these may then be limited further by consideration of cost); (3) output prediction techniques; for stability purposes, the output for the present operating mode is predicted and compared with the desired output of the next iteration; if the difference is within a specified tolerance, the system is kept in its present mode and unnecessary fluctuations are avoided.

With this year's algorithmic development completed, the second year's work will concentrate on the physical construction of the system, the development of a simple computer language to be used in the system, and application of the system to a specific air-mixing/crop-drying problem. As anticipated, the third year's work will be a second application of the system; this will be a crop dryer with liquid storage medium for solar energy having auxiliary heat supplied by a biomass-fueled burner.

PROPOSAL CHANGES

During the first year's work, it became apparent that the specific form of the algorithms used in the system would affect the hardware design to the extent that it was more efficient to begin with a detailed developement of the algorithms. The actual construction of the system then will commence in the second year, along with development of a simple computer language and application of the system to the air-mixing/crop-drying problem. As anticipated, the third year's work will concentrate on a second application of the system; this will be a crop dryer with liquid storage medium for solar energy having auxiliary heat supplied by a biomass-fueled burner.

U.S. DEPARTMENT OF AGRICULTURE
SCIENCE AND EDUCATION ADMINISTRATION Second Year 1981-1982

PROPOSAL BUDGET

Revised Budget OMB-0531-0009

ORGANIZATION AND ADDRESS				DURATION PROPOSED	SEA USE ONLY
Georgia Tech Research Institute Georgia Institute of Technology Atlanta, GA 30332				Months: 12 FUNDS REQUESTED BY PROPOSER	Months: FUNDS APPROVED BY SEA (If different)
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Jay H. Schlag, Albert P. Sheppard					
A. Salaries and Wages	SEA FUNDED WORK MONTHS				
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. 2 (Co)-PI(s)/PD(s)	2.5			$ 9158	$
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. 1 Research Associates-Postdoctorate	2.5			6072	
b. 1 Other Professionals	1.5			3281	
c. 1 Graduate Students				3330	
d. 2 Pre-Baccalaureate Students				4440	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop, and Other					
Total Salaries and Wages				26281	
B. Fringe Benefits (If charged as Direct Costs) 11.59% of A1+A2(a+b)				2145	
C. **Total Salaries, Wages, and Fringe Benefits** *(A plus B)*				28426	
D. Nonexpendable Equipment *(Attach supporting data. List items and dollar amounts for each item.)*				---	
E. Materials and Supplies miscellaneous electronic components				2000	
F. Travel conferences					
1. Domestic *(Including Canada)*				500	
2. Foreign *(List destination and amount for each trip.)*				---	
G. Publication Costs/Page Charges				---	
H. Computer (ADPE) Costs				---	
I. All Other Direct Costs *(Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.)*				---	
J. **Total Direct Costs** *(C through I)*				30926	
K. Indirect Costs *(Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs included in on/off campus bases.)* all on campus, 55% of J				17009	
L. **Total Direct and Indirect Costs** *(J plus K)*				47935	
M. **Less Residual Funds** *(If applicable)*				---	
N. **TOTAL AMOUNT of this REQUEST** *(L minus M)*				$ 47935	$
O. **COST SHARING**	$ 20,000				

NOTE: Signatures required only for Revised Budget

This is Revision No.

NAME AND TITLE (type or print)	SIGNATURE	DATE
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR *J. H. Schlag*		5/15/81
AUTHORIZED ORGANIZATIONAL REPRESENTATIVE *Carol A. Cook*		

Form SEA-55 (Oct 79) Previous edition is obsolete. USDA-SEA

E21-631

QUARTERLY REPORT

Submitted to the
Department of Energy
Through the U.S. Department of Agriculture

from

Georgia Institute of Technology
225 North Avenue, N.W.
Atlanta, Georgia 30332

MICROPROCESSOR-BASED PROCESS CONTROL FOR SOLAR/AGRICULTURAL APPLICATIONS

Principal Investigator

Dr. J. H. Schlag
Professor
Electrical Engineering
(404)-894-2934
SSN 239-52-5477

Project Manager

Dr. A. P. Sheppard
Acting Vice President
for Research
(404)-894-4826
SSN 254-52-4258

January 1981

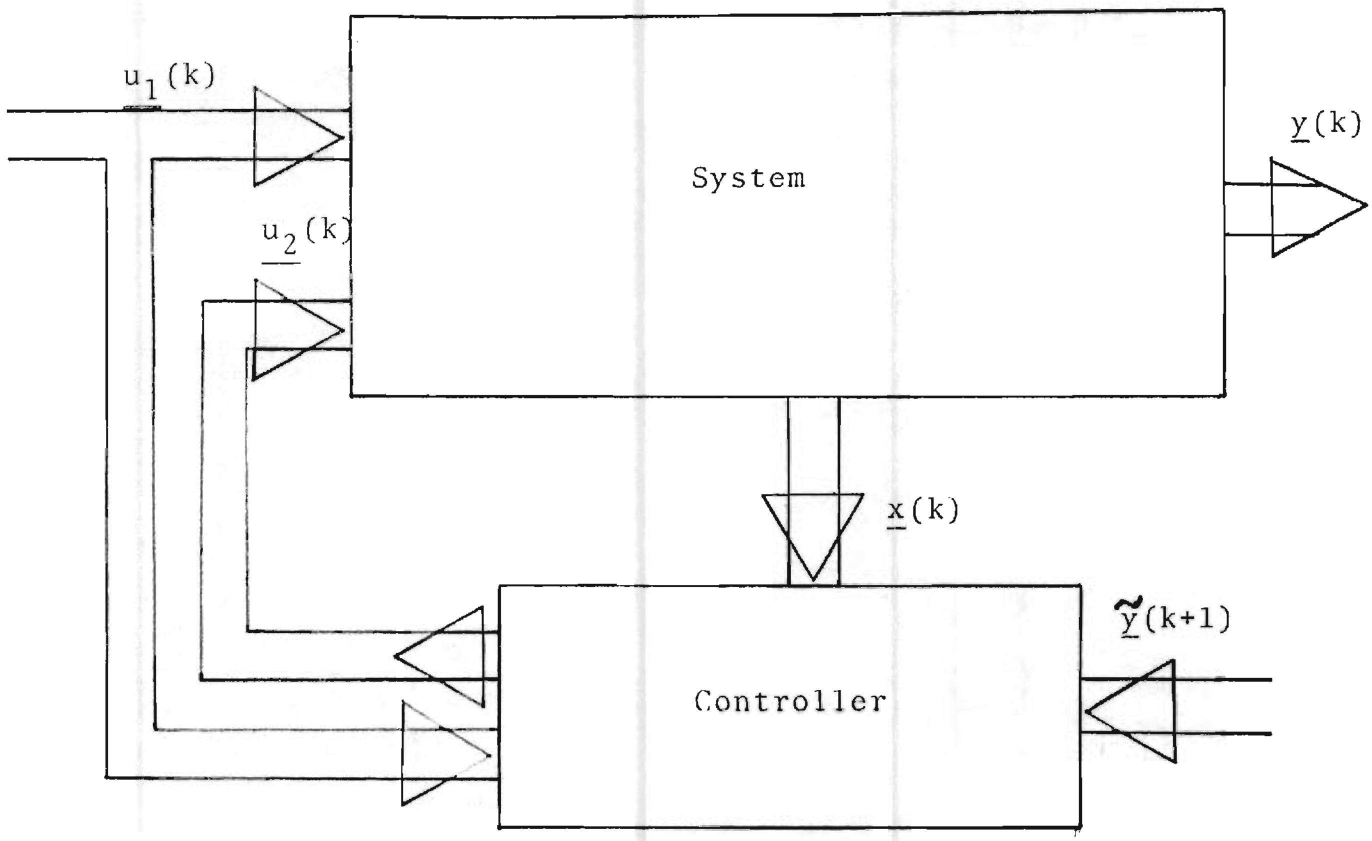
EXECUTIVE SUMMARY

The first few months of this contract period have been spent in the design and construction of a single modular microprocessor system that can be applied to a wide variety of agricultural uses. When completed, this microprocessor controller will be capable of regulating several different kinds of energy sources: direct solar, with either rock or liquid storage; and biomass fuels. It could then regulate the application of this energy to crop drying, biomass distillation, and space heating. The advantages to a standardized control unit are ease of construction and economy of mass production.

The design of this control system has been completed, and hardware construction is now underway. A simplified description of the control problem is included in this report.

In the next quarterly period, construction of the microprocessor system will continue. In addition, algorithms will be developed interrelating the different energy sources with the various agricultural applications to be performed. For example, one algorithm will regulate the use of direct solar-heated air with biomass-fueled heat as auxiliary energy in the drying of peanuts.

THE CONTROL PROBLEM



The symbols in the diagram are defined as follows:

$\underline{u_1}(k)$: at time k, the inputs to the system which are not controllable; i.e., temperatures of ambient air and of solar-heated air from both sources (rock-storage and liquid-storage/heat exchanger). These parameters are input to the controller.

$\underline{u_2}(k)$: at time k, the inputs to the system which are controllable, i.e., the rates of air flow of ambient air and of solar-heated air from both sources; also the amount of biomass-fueled heat.

$\underline{y}(k)$: at time k, the output temperature for a given application (crop drying, biomass fuel generation, or rural heating) and possibly also humidity, if desired.

$\tilde{\underline{y}}(k+1)$: for time k+1, the desired output temperature (and humidity).

$\underline{x}(k)$: the set of possible state parameters for the system; valve angles, burner state (off/on), etc.

It is assumed that the system can be described by a vector ordinary differential equation of the form

$$\dot{\underline{x}} = A\underline{x} + B_1\underline{u_1} + B_2\underline{u_2}$$

and by a vector algebraic equation of the form

$$\underline{y} = C\underline{x}$$

where A, B_1, B_2, and C are matrices.

These equations involving continuous variables can then be discretized to give

$$\underline{x}(k+1) = F\underline{x}(k) + G_1\underline{u_1}(k) + G_2\underline{u_2}(k)$$

and

$$\underline{y}(k+1) = C\underline{x}(k+1)$$

where F, G_1, G_2, and C are matrices.

Given: $\underline{x}(k)$, $\underline{u_1}$ (k), and $\tilde{\underline{y}}(k+1)$

Find: $\underline{u_2}(k)$ such that $y(k+1) = \tilde{y}(k+1)$

$$\underline{y}(k+1) = C\underline{x}(k+1) = C\left[F\underline{x}(k) + G_1\underline{u_1}(k) + G_2\underline{u_2}(k)\right]$$

$$\underline{y}(k+1) = CF\underline{x}(k) + CG_1\underline{u_1}(k) + CG_2\underline{u_2}(k) = \tilde{y}(k+1)$$

$$\therefore \quad \underline{u_2}(k) = \left[CG_2\right]^{-1}\left[\tilde{\underline{y}}(k+1) - CF\underline{x}(k) - CG_1\underline{u_1}(k)\right]$$

Thus the controllable parameters $\underline{u_2}$ are set according to the above dependence on $\tilde{\underline{y}}$, $\underline{x}$, and $\underline{u_1}$.

E21-631

QUARTERLY REPORT

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Project Manager

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Acting Vice President
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SSN 254-52-4258

EXECUTIVE SUMMARY

In the third quarter, work continued on the design of a versatile microprocessor control system for the efficient use of direct solar energy and biomass fuel in various applications; these include crop drying, methane generation, and space heating of rural structures. Emphasis was given to algorithm development and modeling. Also, a general schematic diagram of the proposed system was constructed. Illustrations of these results are included in the following pages.

Future work will include methods of alternating smoothly among the various modes of the system, as well as tailoring the general theory to the specific applications of the solar/agricultural problem.

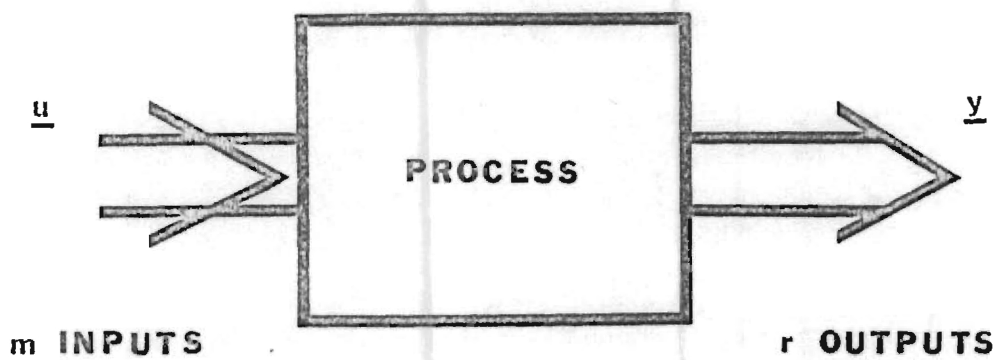
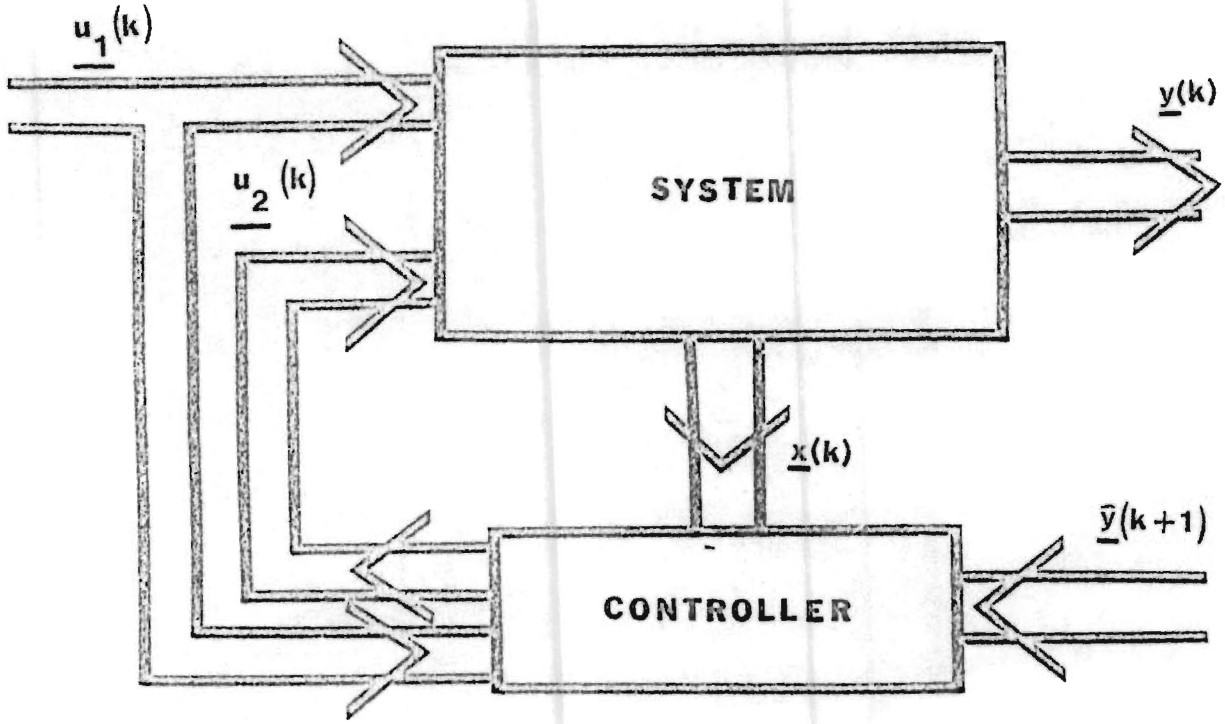
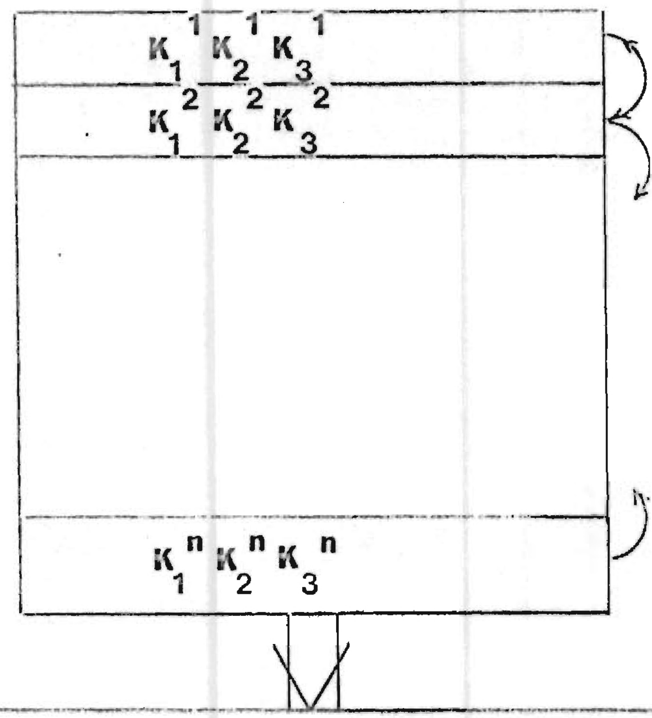


FIGURE 1: PROCESS TO BE CONTROLLED

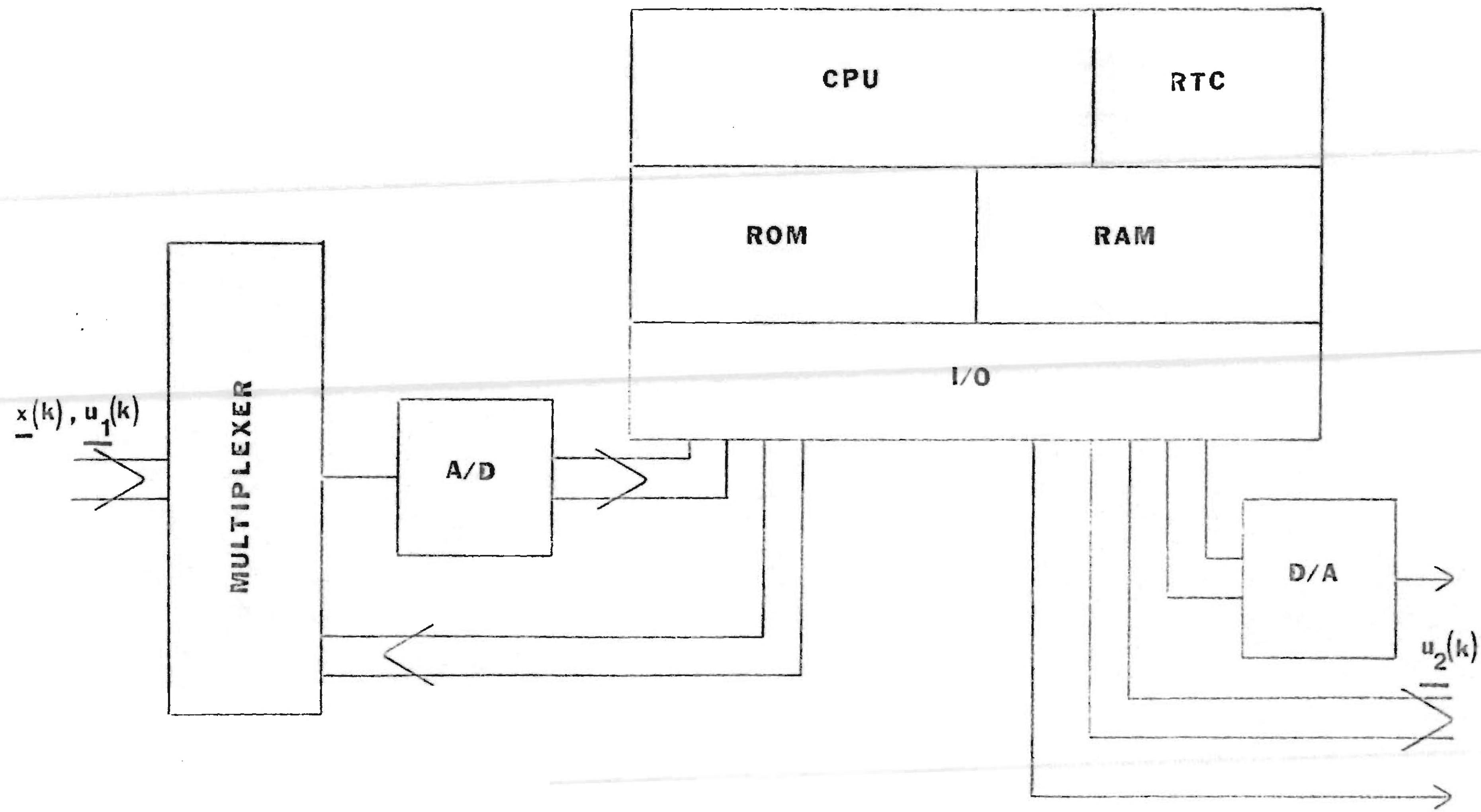
THE CONTROL PROBLEM



MODEL SWAPPING



$$\underline{u}_2(k) = K_1\left[\tilde{y}(k+1) - K_2\underline{x}(k) - K_3\underline{u}_1(k)\right]$$



CPU
RTC
ROM
RAM
I/O
MULTIPLEXER
A/D
D/A
x(k), u1(k)
u2(k)

E-21-631

FINAL REPORT

Submitted to the
Department of Energy
Through the U.S. Department of Agriculture

from

Georgia Institute of Technology
225 North Avenue, N.W.
Atlanta, Georgia 30332

MICROPROCESSOR-BASED PROCESS CONTROL FOR SOLAR/AGRICULTURAL APPLICATIONS

Principal Investigator

Dr. J. H. Schlag
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Project Manager

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Associate Vice President
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(404) 894-4826
SSN 254-52-4258

September 1981

E21-631

During this contract year, work was carried out on the design of a versatile microprocessor control system for the efficient use of direct solar energy (with either rock or liquid storage) and biomass fuel in various applications; these include crop drying, methane generation, and space heating of rural structures. The control problem was defined, and emphasis was given to algorithm development and modeling.